DOCUMENT RESUME

ED 038 324 SE 008 363

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TITLE	Collaborative Practices Between Elementary School Districts and a College in Retraining Teachers for Quality Science Education.
INSTITUTION	San Jose State Coll., Calif. Dept. of Natural Science.
PUB DATE	[70]
NOTE	14p.
EDRS PRICE	EDRS Price MF-$0.25 HC-$0.80
DESCRIPTORS	*Educational Programs, *Elementary School Science, *Elementary School Teachers, *Inservice Teacher Education, Resource Teachers, *Teacher Education, Teaching Procedures

ABSTRACT

Described is a one-year pilot program undertaken to retrain elementary school teachers for remodeling their programs in science education. One purpose of the program was to aid teachers to understand the nature of inquiry learning through activities that combined scientific and quantitative data essential for comprehensive understanding of science. A second purpose was to assist teachers in designing and conducting inquiry centered lessons applicable to children's varying intellectual levels. The teachers' educational experiences were gained through activities in a two-week workshop, then followed by six five-week, three-hour weekly sessions, alternatively scheduled for mathematics and science. During the two-week preparation period teachers studied and practiced inquiry learning episodes, defined behaviors that pupils could achieve, gained understanding of the psychology of instruction necessary for process and conceptual learning, defined the specific roles of teachers and pupils, and considered the nature of desirable facilities for investigative laboratory learning. Administrators of the six school districts involved in this program arranged for release time for resource teachers. Evaluation of the program indicates that changes in teacher behavior and role in guiding learning was achieved. (BR)

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

APR 17 1970

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ED038324

Collaborative Practices Between Elementary School Districts and a College in Retraining Teachers for Quality Science Education

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New patterns for retraining teachers are required if schools are to remodel their programs of science education. For career teachers to keep pace with advances in pedagogy and changes in scientific knowledge, relevant periodic retraining is imperative. Currently, many teachers practice outdated instructional patterns because they maintain mistaken ideas about education. Some believe that telling is teaching, covering the contents of a textbook constitutes learning, and recalling academic factual knowledge is relevant education for children. Such non-functional beliefs and practices may be eliminated by forging new re-educational processes. One pattern for the re-education of teachers was developed by the Departments of Mathematics and Natural Science, San Jose State College, in collaboration with six elementary school districts. The latter selected the teachers to be prepared as resource or laboratory personnel during a one-year pilot program funded by the National Science Foundation.[1]

The experiences of these teachers varied in science background. One had been a former physics-mathematics teacher, a consultant to his elementary district and intermediate grade science teacher. Another teacher's entire

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[1] Jack Fix, San Jose Unified School District
Richard Shepardson and Monica Smith, Campbell Union Elementary School District
Margie Bond, Mt. Pleasant Elementary School District
Ida Carveth, Ravenswood City School District
Ray Bowman, Frank Garcia, and Joyce Malick, Sunnyvale Elementary School District
Susan Lampkin and John Wilson, Whisman School District

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science education had consisted of a nature walk about the school. Regardless of experience, the resource teachers were enthusiastic, creative and industrious; possessed superior intellectual ability; fast learners; and willing to test new ideas. They were flexible in behavior and fluent in creating ideas.

One purpose of the program was to aid teachers to understand the nature of inquiry learning through activities that combined scientific and quantitative data essential for comprehensive understanding of science. A second purpose was to assist teachers in designing and conducting inquiry centered lessons applicable to children's varying intellectual levels. The college staff shared time for formal instruction and field supervision in respective schools located within a 25-mile radius of the college.

PROGRAM OF LEARNING CONDUCTED BY COLLEGE PERSONNEL

First, the teacher's educational experiences were gained through activities in a two-week workshop, then followed by six five-week, three-hour weekly sessions, alternately scheduled for mathematics and science. Formal instruction directed teachers to consider the nature and structure of science and mathematics, nature of inquiry teaching and learning, content of new programs, and responsibilities of resource teachers for improvement of instruction.

The two-week preparation period was conducted to clarify and define the purpose of the year's activity. The teachers studied and practiced inquiry learning episodes, defined behaviors that pupils could achieve, gained understanding of the psychology of instruction necessary for process and conceptual learning, defined the specific roles of teachers and pupils, and considered the nature of desirable facilities for investigative, laboratory learning.

To gain depth in comprehension, each teacher taught two inquiry activities to peers. In consultation with college personnel, each teacher prepared his lessons by stating the operational objectives for developing conceptual understanding, the language of science and mathematics and basic learning skills. Following each teacher's presentation, the lesson was evaluated in terms of standards developed by the group:

> Were the operational or behavioral objectives suitable for the maturity and intellectual readiness of pupils for whom the activities were designed?
>
> Were the analyses of concepts into sub-concepts adequate for the structuring of learning exercises and for assurance that gaps in learning were closed?
>
> Were the task analyses of intellectual processes pertinent and adequate to insure logical, sequential learning of percepts and concepts?
>
> Were the activities structured and listed in accord with the kind of lesson to be taught: inductive, deductive or evaluative?
>
> Was the lesson open-ended to allow for pupil processing of data and creative learning?

At the termination of practice sessions, schemes were formulated with each resource teacher for introducing inquiry learning into his school: first with his homeroom children and then with children in other classrooms.

Formal instruction on campus converged on a variety of learning problems such as:

> Contribution of research to inquiry learning.
> Contribution of Piaget's investigations to the education of children.
> Visitation to curriculum center, University of California, Berkeley.
> Reports of national programs by representatives in the area.
> Attendance at educational meetings.
> Use of field work for the education of children.
> Nature of science education for the preschool child.

Demonstration of learning activities were given by a college staff member who has researched the need with hundreds of preschool children.[2]

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[2]Dr. Frank Gale, Department of Natural Science, San Jose State College.

Time periods were designated for supervision of classroom teaching activities and consultation with college personnel. After each teacher's self-evaluation and college supervisor's appraisal, episodes for the modification of teaching styles and subsequent exercises were designed. Supervisors reported research data that contributed to the specific problem of teaching, analyzed the publications received from curriculum centers developing new programs that would be useful to the teachers, and recommended materials that assisted the teachers. In some instances the supervisor taught the children in order to clarify some facet of learning to present a new approach that deviated from the traditional or to restructure the lesson by reteaching it to gain more depth and breadth.

Each teacher was urged to use his own and children's ideas to create learning activities since creative talents should become ways for building curricula. Each resource person was prodded to use and develop outdoor facilities. Every school possessed an outdoor environment which was unused for investigative learning. Some teachers selected an area adjoining the building or nearby premises for ecological studies. Others decided to construct a setting for the study of environmental factors. Pupils' demonstrations, experiments, charts, posters, pictures, bulletin boards, homemade equipment, tape recordings and many other materials became the media for a children's laboratory.

The resource teacher - college supervisory relationship proved to be a functional, relevant procedure because teachers' understanding of science, inquiry and skillful teaching developed. The teachers' interest in science teaching expanded and many persons relayed their increased fascination to their peer teachers. Some wished to continue at the graduate level, but

subject matter barriers of colleges barred them from pursuing a doctor's degree though their superior ability to teach science to children was evident.

PROGRAM CONDUCTED BY RESOURCE TEACHERS IN RESPECTIVE SCHOOLS

Administrators, in cooperation with project directors, arranged for released time for resource teachers to meet with college staff for subsequent planning of work, demonstrating inquiry learning in different grades, observing other resource teachers, and securing materials and equipment from various community centers. Because the local college maintains a Materials Center, teachers secured many needed devices; many of which served as models for the construction of school's equipment. Substitute teachers, retained by the districts, assumed responsibilities for the home rooms while the resource personnel taught in other classes.

The resource teacher continued his retraining, beyond the workshop experiences, by testing out and perfecting his teaching skills with his own class. When he had gained confidence in guiding children in the use of inquiry skills, he began to plan lessons with teachers who invited assistance. He visited with teachers who manifested reluctance to use a peer's assistance. To break the barrier, the resource person offered to provide materials useful to the peer teacher, inquired about sections of a text that was most interesting and parts of science that were difficult to maneuver with children. After several visits during coffee breaks and lunch times, the resource teacher offer and asked for some time to learn the status of childrens' knowledge and interest in science. Through the above procedures the disinterested teachers became active, interested participants. Some were completely won over and found inquiry teaching fun. The disinterested teachers were those

whose college science experiences had been neglected. When teachers comprehended that exploring, probing, and seeking are biological attributes of children then attitudes changed from unconcern to concern for providing needed science studies.

Each demonstration lesson by the resource person was planned with the peer teacher to accommodate the design commensurate to intellectual readiness of pupils. Purposes were defined as behaviors that supported operations leading to concept formation and comprehension of some conceptual scheme. Emphasis on how to guide learning was a prime consideration. After the presentation, the activity was critiqued by the teachers, a college supervisor, principal, or the curriculum coordinator. Decisions were made jointly for subsequent needed process learning, content and skill experiences to be pursued by the peer or resource teacher. Some teachers succeeded in reaching every peer teacher and providing workshop experiences for the retraining of their peers. Certain principals and curriculum coordinators assisted in procuring such success in their respective schools. However, in a few schools the local resources were not centered on the project; this limited the gains from available professional assistance.

Resource teachers assumed responsibility to augment and obtain needed equipment. Some constructed devices; some acquired free materials from shops and industries; others collected appropriate, suitable materials from the natural environment but were careful to conserve the natural resources. Investigations and films showing Piaget's contribution to the education of children were presented by a few teachers.

Teachers trained certain pupils in their assigned class to be laboratory assistants. These assistants helped to assemble equipment, prepare certain

materials, and arrange the contents on a cart which was wheeled into each classroom. Every teacher encouraged each child to teach another child some skill or process in acquiring data that became an asset to learning.

The one-to-one interaction process (teacher with teacher) was a successful, relevant procedure for re-education of teachers for several reasons: The friend, partnership, fellowship feeling enabled resource teachers to adjust their experiences to a peer teacher's flexibility to change, an ability to guide inquiry learning, and a comprehension of the nature and meaning of science. As teachers' understanding of science processes increased, more opportunities were provided for pupil decision making. Most of the resource teachers continued as teaching specialists for the school after the close of the pilot program because plans and programs have taken shape.

EVALUATION OF THE PROGRAM

Evaluation of practices is pertinent if persons responsible for teacher education are to reconstruct their practices. An appraisal of teaching should pertain to cognitive learning, attitudes, and skills. For teachers to obtain these ends, educators of teachers will need to create experiences that raise the quality of learning above the level of repeating, memorizing, reciting and recalling.

During the year's activities, teacher behaviors and teacher-pupil interaction analyses gave clues to the effectiveness of the staff's formal instruction and the teachers' inquiry guidance of children. Four systems of evaluation were used to obtain evidence:

1. Identification of teachers' role in inquiry learning obtained periodically through eight months' duration of supervision.

2. Teachers' standards for self-evaluation of practices obtained through teacher-teacher dialogue.

3. Resource teachers' contribution to peers obtained through an interview conducted by a person not associated with the project.[3]

4. Resource teachers' contribution to children's education obtained through a terminal questionnaire.

1. Identifying the Teachers' Role in Inquiry Learning

The behaviors that suggest the role of the teacher in inquiry learning were defined, observed, analyzed and organized as indicated below.

a. Defined role: Teachers should give pupils opportunities to make decisions such as: giving ideas for investigation, suggesting ways to investigate, formulating standards for self-evaluation, and finding their own information. Evidences shown by teacher's behavior:

Accepts suggestions for improvement of investigative procedure.

Asks for statement of questions or hypotheses.

Accepts information processed by pupils.

Gives pupils opportunity to state and interpret own data.

Directs pupils' attention to a novel way in which a child uses equipment, collects evidence, communicates information.

Uses questions that require pupils to make decisions:

What new idea is Jane investigating?
What other investigation can you do?
How can you improve your investigation?
What is the question you are investigating?
How can you test your hypothesis or hunch?
What can you do to get more information?
How have you learned to obtain good information?

b. Defined role: Teachers should assist pupils to specify standards for self-evaluation of learning such as: stating criteria or guides for learning. Evidence shown by the teacher's behavior:

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[3]Tim Aaronson, graduate student, Department of Natural Science, 1968-69.

Accepts statements and ideas offered by pupils when based upon individual or group processed information.

Provides materials for pupils to develop and test ideas that are accurate, adequate and pertinent to a question or hypothesis.

Guides and accepts standards that children propose for making a graph, writing a paragraph, designing an investigation, evaluating an experiment and constructing evaluations.

Gives time for pupils to evaluate their learning in terms of the standards.

Uses questions that guide pupils to formulate standards of value to them:

What do you need to do to set up a good experiment?
Where should you look for the best information?
What kind of things can you do to obtain the best answers to your questions?
What did you find out when you tested more than one magnet?
What are the ways that help you to learn?
What is the value of the exercise to you?

c. Defined role: Teachers and other school personnel should provide a suitable social environment for inquiry-laboratory practices such as guiding and assisting pupils in laboratory investigative learning, obtaining child-centered materials and equipment, and guiding pupils to develop self-discipline for inquiry learning.

Evidences shown by teacher's behavior:

Supplies appropriate materials for measuring, testing, and producing learning activities.

Demonstrates how materials and equipment are manipulated that enable pupils to continue their own investigations.

Develops social standards with pupils that enable them to work effectively with other pupils.

Guides children to formulate ways that they can teach each other.

Asks children to evaluate their work habits in terms of standards formulated by the group or individuals.

Uses teacher-pupil planning periods to make decisions for investigative learning.

Guides pupils to define and identify ways that science is studied.

Uses questions that guide pupils to control social behavior and engage in self-learning:

> What are some things you should do so that each one has a chance to do what he wants to do?
> What can you do so that each one has a chance to use the few devices we have?
> What can you do when you have completed your investigation?
> What are ways that we can help each other?
> What kind of behavior will work so that each one is free to do what he has planned?
> What are ways that help you learn?
> How can you report what you have learned?
> How can you care for your materials?

2. Teachers' Standards for Self-evaluation

Oral statements made by resource teachers during conference periods indicated changes in comprehension of inquiry learning:

> Science has to be child-oriented if you expect them to get something out of it.
>
> If you have planned an activity, you have to show whether children are ready to learn from it. If pupils don't have some skill for measuring or the use of the metric system, they will have trouble in getting good information.
>
> You have to use some teaching patterns or ways to show children what to do so they can learn.
>
> I am learning how I can guide my pupils to form concepts. Science is fun when you can start where the children are.
>
> I am planning my activities so that I can teach myself the meaning of inquiry.
>
> I am teaching my children all kinds of measurement that help them to learn science.
>
> When you state your objectives, you know what you are doing. I plan more carefully than I did before.
>
> We haven't yet learned how to evaluate children to find out how they think.

> My idea of sequence in learning has been changed. I thought that every child had to do some of the same things so he would be ready for the next grade. Subject matter is important, but he has to know how to learn.

Vocabulary used by teachers indicated that innovations had been tried: child-centered curriculum, pupils' intellectual level of understanding, open-ended exercises, process learning, invention and discovery learning, perceptual and conceptual learning. Individual teachers reported that they had increased the use of mathematics, used science as part of reading readiness activity, increased oral skills and increased participation of the science shy. More flexibility was recognized because of the acquaintance with new programs and repeated encouragement to create children's activities.

Teachers seemed to be convinced that their teaching was better because pupils looked forward to science and more pupils in the school were receiving science instruction. Certain teachers found that a few pupils prefer to "look things up" rather than "finding out for themselves."

The number of peer teachers reached in the school increased from zero to ten. Each resource teacher retrained an average of six peer teachers.

3. Resource Teachers' Contribution to Peers

Results of the interview with resource teachers gave more insight into changes of teaching strategy. Excerpts from the graduate students' papers reveal that the typical program in the past "had consisted of rare experiences in science linked heavily with the science weekly reader or science textbook and rarely with experiments." The most noticeable and most easily measured change in the activities of the participating teacher was the increased time allotment to science.

Several activities were unique. One kindergarten teacher became a resource person for several primary teachers. Also, she conducted workshop activities for primary teachers, and an inservice demonstration of inquiry learning for about 50 teachers. Three other resource personnel conducted demonstration activities for teachers in their school districts. Five teachers reported that they were arranging for a continuous program for their school.

Teachers appreciated the opportunity to have teaching strategies critically examined by professionals and they also appreciated the enthusiasm which the college staff expressed for the teachers' efforts. A major criticism was the lack of concerted effect to unify many aspects of mathematics with science which an extended period of time would have provided. Resource personnel stated that principals should become intimately involved with a program.

4. Resource Teachers' Contribution to Children's Education in the School

Descriptions of classroom and school events were obtained from a terminal questionnaire. The instrument substantiated the above enumerated results. Other definitive outcomes were cited by resource personnel:

The nature of science objectives were clarified.

The nature of science was more adequately comprehended.

Science periodicals that explain the nature of science instruction were ordered for the school.

Peer teachers became willing to participate in developing operational objectives.

Basic skills were increasingly used in developing conceptual meaning.

Evaluation of learning was expanded; not confined to observational data.

Science information was used in social studies, health education, and language.

New elementary science programs were increasingly used by teachers to modify the program for children.

Children were willing to explore, test answers and share their findings.

Best sources were sought for by children.

A tutorial program was developed for science instruction.

Newspaper stories were submitted.

Mathematical processes found useful in developing conceptual understanding included these:

Use of arbitrary standards
Use of metric system and tools for measurement
Method of recording and graphing
Arrangement of numbers in series
Comparison of quantitative data
Use of simple statistical procedures
Use of paired numbers
Extrapolation of numbers to form a concept
Measurement and meaning of volume, weight, pressure, time, area, distances, temperature
Identification of shapes and sizes
Use of decimals and fractions
Study of geometric figures
Statement of simple formulae
Design of procedures for timing events
Demonstration of number relationships
Classification of number of objects
Counting (structures on plants per unit area)
Positive and negative numbers

NEEDS ENCOUNTERED DURING THE PILOT PROJECT

Certain needs, made evident during the project, should be incorporated in a re-education program for teachers. Principals of participating schools should participate in the planning in order to understand the intent of instruction, the need for time, equipment, and facilities for teaching science. One-half of the resource teacher's time in the school should be allowed for contact and demonstration work with teachers. The program based upon the

reported objectives of the pilot program should be extended for a two-year period to enable participants to increase their skill as resource teachers. Application of mathematics to science is mandatory.

Evaluation should be conducted as a program develops in the schools. Problems that may be researched pertain to progress made by pupils in productive thinking, processes for concept formation, application and growth in basic skills, changes in attitudes and values. Improving the climate for learning and analyzing teacher behaviors that affect pupils' quality of learning constitute other needed research. Graduate students from all departments on a campus may be recruited to research the problems to obtain data for the improvement of childrens' education.

Criteria for the selection of teachers and participating schools are mandatory for the successful training of resource personnel. The coaching process may be started in a four-week workshop to develop more skillful teaching acts than the present reported workshop provided. Full-time supervision of selected college staff is essential if each teacher is to receive adequate assistance in developing an on-going program.

IMPLICATIONS FOR TEACHER EDUCATION

Changes in teacher behavior and role in guiding inquiry learning may be achieved by focusing the attention on teaching acts. Modification of traditional roles to reach more modern practices will occur when teachers establish standards for developing and evaluating practices in direct contact with children. In order for teachers to confront the realities of their own procedures they must acquire immediate feedback on the relevance of learning activities. Collaborative practices among public school teachers and administrators, professional science educators, scientists, and mathematicians will enhance and hasten the creation of appropriate science curricula and the design of strategies for learning in a school.